5.2. Plant population trends in Sierra Nevada

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Abstract

The annual monitoring of the populations of *Laserpitium longiradium* Boiss., *Arenaria nevadensis* Boiss & Reut., *Gentiana lutea L.* subsp. *lutea*, and *Senecio nevadensis* Boiss & Reut. were evaluated for their state of conservation to identify factors determining their population dynamics. The population of *L. longiradium* showed no net changes in its distribution, or abundance, nor in its population structure in the last 14 years. The distribution areas of *A. nevadensis* diminished over the time series, while its density and accompanying species slightly increased. *G. lutea* subsp. *lutea* also showed stable demographic features, fundamentally due to the longevity of the specimens. In the year following the installation of the exclusion fences, the percentage of reproductive individuals with dispersal capacity substantially increased. However, no seedlings were found to be present. Meanwhile, *S. nevadensis* increased the population abundance above 3000 m.a.s.l., but lower than this elevation the number of individuals markedly diminished.

Aims and methodology

Laserpitium longiradium: To monitor the population structure of this species, each specimen was categorized into one of these demographic stages: seedling, juvenile, vegetative adult and reproductive adult.

Arenaria nevadensis: The extent, demography, and reproductive capacity was analysed in two populations: Veta Grande (one nucleus) and Mulhacén (three nuclei). The number of individuals were counted annually by fixed transects. At each site, 30 individuals taken at random were measured for size and number of reproductive structures, as well as density, measuring the minimum inter- and intraspecific distances.

Gentiana lutea subsp. *lutea*: The life stage was recorded annually (seedling, juvenile, vegetative or reproductive), as well as the size of each individual, its reproductive capacity by the quantity of flower verticils, the number of fruits, and herbivore damage. The impact of herbivory was measured by comparing the above variables in areas protected by fences that excluded livestock with respect to adjacent areas without fencing in four types of microhabitat: meadow, meadow-spiny broom shrubland, spiny broom shrubland, and rocky areas.

Senecio nevadensis: The abundance of *S. nevadensis* was studied in plots with a circular shape 10 m in diameter, distributed over an elevational gradient of between 2775 and 3150 m.a.s.l.. The elevational range described for the species ranges from 2600 to 3300 m.a.s.l. [5].

Results

After 14 years of monitoring, the demographic structure of *L. longiradium* remained stable, although subject to slight annual fluctuations (Figure 1a and b). The vegetative specimens clearly dominated, followed by juveniles, reproductive specimens, and seedlings. The number of reproductive adults and of the seedlings 2 years later (recruitment) were correlated (ρ_2= 0.514). Also, there was a correlation between the juveniles and vegetative adults, taking into account the lag of one and two years (ρ_1=0.844, ρ_2=0.803).

A reduction in the distribution area of *A. nevadensis* was noted together with a slight increase in the density of the accompanying species (Figure 2b).

The reduction in the distribution area was clearer in the nucleus of Veta Grande, while those of Mulhacén presented greater fluctuations between years (Figure 3 a). The average number of the reproductive structures fell during the monitoring the period (Figure 3 b).

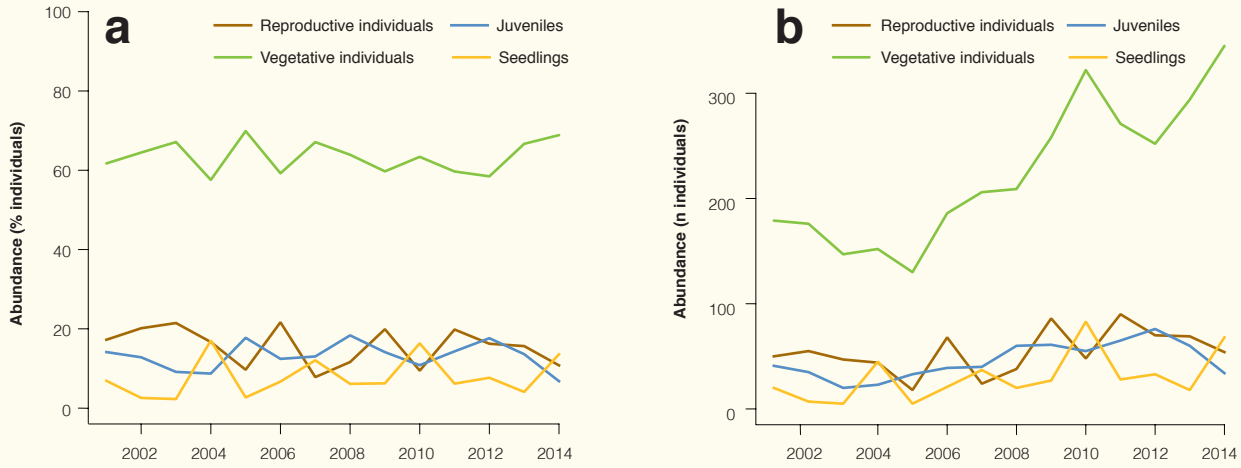
The population of *G. lutea subsp. lutea* did not vary substantially in the last 5 years. The growth rate remained stable. No seedlings were found, nor did any specimen die. The phenomenon of latency was frequent.

From the elasticity analysis [6], it was concluded that the specimens remaining in the vegetative stage, first, and those that become reproductive, second, are the transitions that most provide stability of population size (Figure 4).

The fences to exclude livestock clearly benefited the reproductive capacity of this species. The reproductive specimens inside the fenced areas (Figure 5) increased significantly (x^2=96.95, p<0.001) as well as the capacity to produce a greater number of fruits (x^2=188, p<0.001).

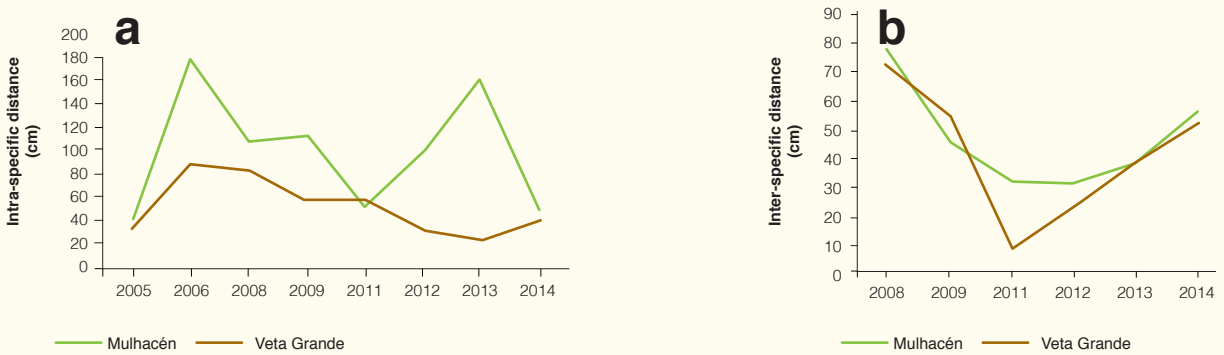
The number of *S. nevadensis* individuals remained constant, considering the total of the sites studied during the last 4 years of the monitoring. The populations situated above 3000 m.a.s.l. slightly increased in abundance, while those below presented the reverse pattern (Figure 6). In fact, at 50% of the sites studied, the abundance fell (most being below 3000 m.a.s.l.) whereas 42% augmented and 8% remained stable. The number of reproductive individuals fell considerably over the study period (Figure 7).

Figure 1



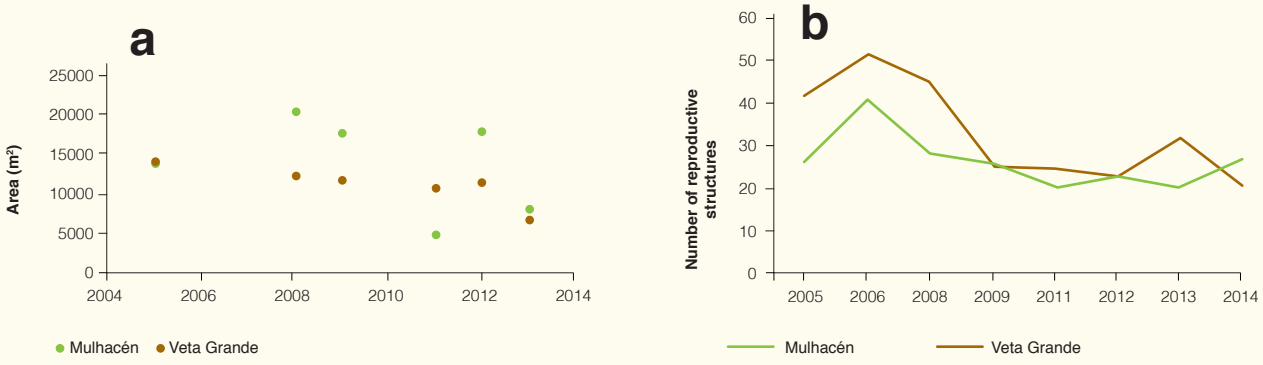
Temporal evolution (years) of each stage of population development of *L. longiradium*: a) relative values (%); b) absolute values.

Figure 2



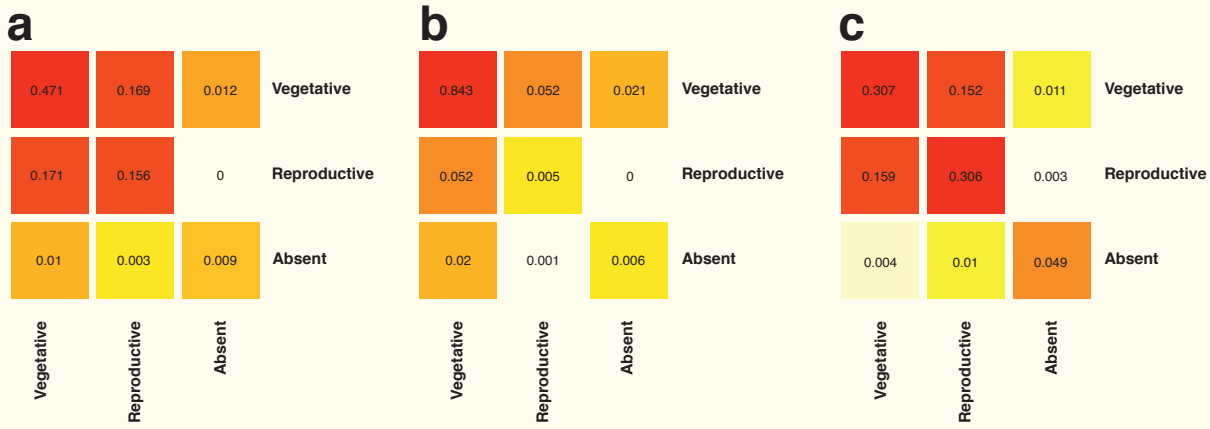
Temporal evolution of density of *A. nevadensis* individuals in comparison to other species in the habitat (expressed as the mean distance to the nearest individual in cm, n=30). Intraspecific (a) and interspecific distance (b).

Figure 3



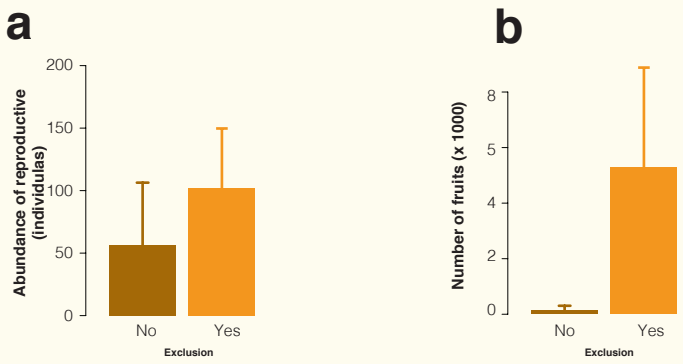
Temporal changes (years) in the distribution area (a) and in the number of reproductive structures per site (b) of *A. nevadensis* during the period 2005-2014 (n=30).

Figure 4



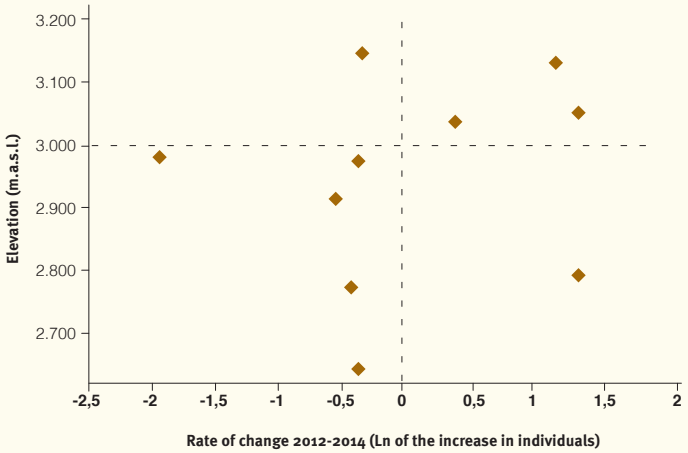
Elasticity plots of the population of *G. lutea* subsp. *lutea*. (a) General between 2010-2014; (b) Transitions 2010 and 2011; (c) Transitions 2013 and 2014.

Figure 5



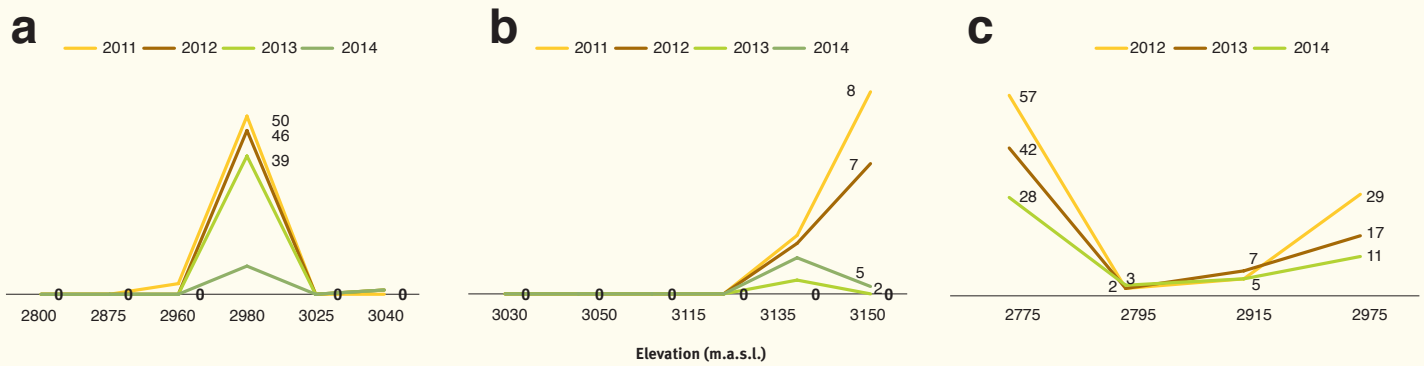
Effects of the exclusion of livestock in abundance of reproductive individuals (a) and abundance of fruits (b)

Figure 6



Changes in abundance over an elevational gradient (for the sites sampled: Veta Grande, Mulhacén, and Veleta).

Figure 7



Changes inf abundance of reproductive individulas by site (2011-2014) in absolute values: (a) Mulhacén, (b) Veleta y (c) Veta Grande.

Discussion and conclusions

The populations of *L. longiradium* (14 years of monitoring), *A. nevadensis* (9 years of monitoring), *G. lutea* subsp. *lutea* (4 years of monitoring), and *S. nevadensis* (4 years of monitoring) presented a stable trend, over the short term. *Laserpitium longiradium* showed no changes in its population structure during the study period. Its continuity depended only on the maintenance of the characteristics of the habitat it occupied and the continuation of conservation measures begun.

Arenaria nevadensis populations remained relatively stable, given the fluctuations to be expected from an annual species of these high-mountain environments. Density was variable over the study period, especially at the Veta Grande site, but there was an appreciable trend towards an increase. The reproductive capacity (number of reproductive structures) continued to decline. Nevertheless, the continuity of this species is subjected to risks inherent in this restriction to isolated enclaves. In this sense, the results of a genetic study [7] point to a low dispersal capacity as a limiting factor for the expansion of the species and to risk of genetic depression by inbreeding, given the low genetic flow between its core populations.

The monitoring of *Gentiana lutea* subsp. *lutea*, indicated the effectiveness of the conservation works undertaken. Although highly beneficial for its reproductive capacity, the expected positive effect on recruitment was not detected. The

elasticity analysis implies that the longevity of these adult specimens is a key factor in the persistence of the population. According to other studies [8], the viability of the seeds is very sensitive to population size.

The population of *Senecio nevadensis* registered positive growth rates at its upper elevational limit, above 3000 m.a.s.l.. However, this increase was not generalized at all the sites, so that other factors might be involved, such as the rocky structure, unstable soil, and herbivory. The effect of herbivores may be important, both for the browsing as well as moderate nitrification [9]. The reproductive rate diminished in the monitoring period and showed notable annual fluctuations. For its late flowering, the species is characterized by showing marked fluctuations in fruit production and seedling recruitment in relation to colder years during the critical period for reproduction [9]. This may explain the differences detected and could represent a limitation for the species conservation.

Gentiana lutea subsp. *lutea*